whole lifetime, and let us use them by giving living and intelligent learning, not obsolete and parrot instruction. Those who are believers in the teaching of the great secondary schools of this country will deem my aspirations for the improvement of primary education, low and utilitarian. Frankly I admit the latter. Such a style of education will never realise Lord Brougham's hope that the time may come when every working man in England will read Bacon ; but it might contribute to the fulfilment of Cobbett's desire, that the time might come when every man in England could eat bacon. I deny, however, that the utilitarian view of primary education is ignoble. The present system is truly ignoble, for it sends the working man into the world in gross ignorance of everything that he is to do in it. The utilitarian system is noble, in so far as it treats him as an intelligent being, who ought to understand the nature of his occupation, and the principles involved in it. The great advantage of directing education towards the pursuits and occupations of the people, instead of wasting it on dismal verbalism, is that, while it elevates the individual, it at the same time gives security for the future prosperity of the nation. In the industrial battles of peoples, we are content to leave our working classes armed with the old Brown Bess of warfare, while men of other countries are arming themselves with modern weapons of precision. In the competition of nations, the two factors of industry—raw material and intellect, applied to its conversion into utilities—are altering their values. The first is rapidly decreasing, the second quickly augmenting in value. We anchor our hopes on the sand, which the advancing tide of knowledge is washing away, while other nations throw out their anchors on firm ground accumulating around, and enabling their vessels to ride in safety. There are instances of nations, rich in the natural resources of industry, yet poor from want of knowledge how to apply them ; and there are opposite examples of nations utterly devoid of industrial advantages, but constituted of an educated people who use their science as a compensation for their lack of raw material. Spain is an example of the first class, and Holland of the second. Having pointed out at some length the contrast between these two countries, in consequence of the difference of their culture, Dr. Playfair proceeded to show the necessity of good physical training, to argue in favour of a compulsory educational system, and of graded education, and to define the true position and qualifications of teachers in primary schools.

THE BRITISH ASSOCIATION

LECTURE ON STREAM LINES IN CONNECTION WITH NAVAL ARCHITECTURE, BY PROF. RANKINE

THE lecturer stated that his object was to give a brief summary of the results of some application of the mathematical theory of hydrodynamics to questions regarding the designing of the forms of ships, and the mutual actions between a ship and the water in which she floats. The art of designing the figures of ships had been gradually developed by processes resembling those called "natural selection," and the "struggle for existence" in the course of thousands of years, and had arrived in skilful hands at a perfection which left little more to be desired, when the object was to design a ship that should answer purposes and fulfil conditions which had previously been accomplished and fulfilled in the course of practical experience. But cases now frequently arose in which new conditions were to be fulfilled; and purposes accomplished beyond the limits of the performance of previous vessels, and in such cases the process of gradual development by practical trials made without the help of science was too slow and too costly, and it became necessary to acquire and to apply scientific knowledge of the laws that regulate the actions of the vessel on the water and of the water on the vessel. Amongst the questions thus arising were the following : What ought to be the form of the immersed surface or skin of a ship in order that the particles of water may glide smoothly over it? And, the form of such a surface being given, how will it affect the motion of particles in its neighbourhood, and what mutual forces will be exerted between the particle of water and that surface? Practical experience, unaided by science, answers the first question by saying that the surface ought to belong to a class called "fair surfaces" (that is, surfaces free from sudden changes of direction and of curvature) of which various forms have in the course of ages been ascertained by trial, and are known to skilful shipbuilders. That answer is satisfactory so far as it goes ; but in order to solve problems involving the mutual actions of the ship and the water, something more is wanted, and it becomes necessary to be able to construct fair surfaces by geometrical rules based on the laws of the motion of fluids, and to express their forms by algebraic equations. There were many very early attempts to do this, but through not being based on the laws of hydrodynamics, they resulted merely in the finding of empirical rules for reproducing when required forms which had previously been found to answer in practice, and did not lead to any knowledge of the motions of the particles of water or of the forces exerted by and upon them ; and they had little or no advantage over the old process of modelling by the eye and hand, and of "fairing" the lines with the help of an elastic rod called a "batten." As regards this process, indeed, the mathematical methods about to be referred to are to be regarded, not as a substitute for it in designing the form of a ship, but as a means of arriving at a knowledge of the mutual actions between her and the water, which the old process is incapable of affording. The earliest method of constructing the figures of ships by mathematical rules, based on hydrodynamical principles, was that proposed by Mr. Scott Russell about twenty-five years ago, and since extensively practised. It consisted in adopting for the longitudinal lines of a ship curves imitated from the outlines of waves in water. The motions which surfaces formed upon this model impress on the water were known to a certain degree of approximations. These "wave-lines," however, although they were fair curves in the sense already mentioned, were by no means the only fair curves, but were only one class out of innumerable classes of curves having the property of gliding smoothly through the water; and it was well known in practice that vessels had proved successful whose lines differed very widely from wave-lines. It was therefore desirable that methods should be devised of constructing by mathematical rules based on the laws of the motions of fluids, a greater variety of curves possessing the requisite property of fairness, and not limited to the wave-line shape. Such had been the object of a series of researches that had been communicated to the Royal Society at different dates since 1862. They related to the construction of what it has been proposed to call stream-lines. A stream-line is the track or path traced by a particle of water in a smoothly and steadily flowing current. If, when a ship is gliding ahead through the water with a certain speed, we imagine the ship to be stationary, and the water to be flowing astern past the ship in a smooth and steady current with an equal average speed, the motions of the ship and of the particles of water relatively to each other are not altered by that supposition; and it becomes evident that if the form of surface of the skin of the ship has the property of fairness, all the tracks of the particles of water, as they glide over that surface, are stream-lines, and the surface itself is one containing an indefinite number of stream-lines, or, as it has been called, a stream-line surface. It is also to be observed, that when we have deduced from the laws of the motion of fluids the relations which exist between the form of the stream-lines in different parts of a current, and between those forms and the velocities of the particles as they glide along different parts of those lines, we know the relations between the form and speed of a ship whose surface coincides with a certain set of these stream-lines, and the motions of the particles of water in various positions in the neighbourhood of that ship. The lecturer then proceeded to explain, and to illustrate by diagrams, the methods of constructing stream-lines. These methods were based upon the application to stream-lines in a current of fluid of a mathematical process which had previously been applied by Mr. Clerk Maxwell to lines of electric and magnetic force. A current of fluid is represented on paper by drawing a set of stream-lines so distributed that between each pair of them there lies an elementary stream of a given constant volume of flow. Thus, while the direction of flow is indicated in any given part of the current by the direction of the stream-lines, the velocity of flow is indicated by their comparative closeness and wideness apart, being evidently greatest where these lines lie closest together, and least where they are most widely spread. If, upon the same sheet of paper, we draw two different sets of stream-lines, these will represent the currents produced in one and the same mass of fluid by two different sets of forces. The two sets of lines form a network, and, if through the angles of the meshes of that network we draw a third set of stream-lines, it can be proved from the principle of the composition of motions, that this third set of lines will represent the current produced in the same mass of fluid by the combination of the forces, which, acting separately, would produce the current represented by the first two sets of stream-lines respectively. The third set may be called the resultant stream-lines. Suppose, now, that a third set of component stream-lines are drawn representing the current produced by a third set of forces: this will form a network with the previously drawn resultant stream-lines, and a set of lines drawn through the angles of the meshes of this new network will represent the resultant current produced by the combination of the three sets of forces; and so on to combinations of any degree of complexity that may be required. In order to draw a system of stream-lines suited for the longitudinal lines of a ship, three sets at least of component stream-lines must be combined. One of these is a set of parallel straight lines, representing a uniform current, running astern with a speed equal to the actual speed of the vessel. A second set consists of straight lines radiating from a point called a focus in the forepart of the vessel, and they represent the diverging motion that is produced by the ship displacing the water near her bows. The third set of component stream-lines consists of straight lines converging towards a second focus in the afterpart of the vessel; and they represent the motion of the water closing in astern of the ship. The resultant stream-lines thus produced present a great variety of forms, all resembling those of actual ships having all proportions of length to breadth, and all degrees of bluffness and fineness at the ends, ranging from the absolute bluffness of a sort of oval to a bow and stern of any degree of sharpness that may be required. It has been proposed to call stream-lines of this sort Oögenous Neoïds; that is, ship-like lines generated from an oval, because any given set of them can be generated by the flow of a current of water past an oval solid of suitable dimensions. The properties of these curves were investigated in 1869. They have, however, this defect, that the absolutely bluff ovals are the only curves of the kind that are of finite extent; all the fixed curves extend indefinitely in both directions, ahead and astern; and in order to imitate the longitudinal lines of a fine-ended vessel, a part only of some indefinitely extended curve must be taken. In 1870 an improvement in the construction of such curves was introduced, by which that defect was overcome; it consisted in the introduction of one or more additional pairs of foci, involving the combination of at least five sets of component stream-lines. By this device it is possible to imitate longitudinal lines of actual vessels by means of complete closed curves, without rising portions of indefinitely extended curves; and thus the motion of the particles of water, as shown by the stream-lines that lie outside the closed lines representing the form of the vessel, becomes more definite and accurate. The lecturer mentioned that the idea of employing four foci and upwards had been suggested to him by the experiments of Mr. Froude on the resistance of boats modelled so as to resemble the form of a swimming bird; for which purpose stream-lines with four foci are specially adapted. It has been proposed to call such lines Cycnogenous Neoïds—that is, ship-like curves of shapes like that of a swan. In such curves the outer foci—that is, the foremost and aftermost—are situated in or near the stem and sternpost of the vessel, which are represented in plan by small horse-shoe curves, as if they were rounded off at the corners instead of being squared, as in ordinary practice. The inner foci are situated respectively in the fore and after body. When the foci of the longitudinal lines of a vessel have been determined, the proportion borne by the aggregate energy of the motion impressed on the particles of water to that of the motion of the vessel herself can be approximately determined. The lecturer next proceeded to explain the bearing of some of the mechanical properties of waves upon the designing of vessels, especially when these properties are taken in combination with those of stream-lines. It had long been known that ships, in moving through the water, were accompanied by trains of waves, whose dimensions and position depended on the speed of the vessel; but the first discovery of precise and definite laws respecting such waves was due to Mr. Scott Russell, who published it about twenty-five years ago. The lecturer now described in a general way the motions of the particles of water in a series of waves, and illustrated them by means of a machine designed for that purpose. He showed how, while the shape of the wave advances, each individual particle of water describes an orbit of limited extent in a vertical plane. The periodic time of a wave, its length, the depth to which a disturbance bearing a given ratio to the disturbance at the surface of the water extends, and its speed of advance, are all related to each other by laws which the lecturer explained. He then stated that Mr. Scott Russell had shown that when the vessel moved no faster than the natural speed of advance of the waves that she raised, these waves were of moderate height, and added little or nothing to her resistance; but when that limit of speed was exceeded, the waves and the resistance caused by them increased rapidly in magnitude with increase of speed. His own (Professor Rankine's) opinion regarding these phenomena was, that when the speed of the vessel was less than or equal to the natural speed of the waves raised by her, the resistance of the vessel consisted wholly, or almost wholly, of that arising from the friction of the water gliding over her skin; and he considered that this opinion was confirmed by the results of practical experience of the performance of vessels. The wave motion, being impressed once for all on the water during the starting of the vessel, was propagated onward like the swell of the ocean, from one mass of water to another, requiring little or no sensible expenditure of power to keep it up. But when the ship was driven at a speed exceeding the natural speed of the waves that she raised, these waves, in order to accompany the ship, were compelled to spread outwards instead of travelling directly ahead; and it became necessary for the vessel, at the expense of her motive power, to keep continually originating wave-motion afresh in previously undisturbed masses of water; and hence the waste of power found by experience to occur when a ship was driven at a speed beyond the limit suited to her length. This divergence or spreading sideways of the train of waves had a modifying effect on the stream-lines representing the motions of the particles of water. It caused them, in the first place, to assume a sinuous or serpentine form; and then, instead of closing in behind the ship to the same distances from her course at which they had been situated when ahead of her, they remained permanently spread outwards. In other words, the particles of water did not return to their original distances from the longitudinal midship plane of the vessel, but were shifted laterally and left there, much as the sods of earth are permanently shifted sideways by the plough. The place of the water which thus fails to close in completely astern of the vessels is supplied by water which rises up from below and forms a mass of eddies rolling in the wake of the ship. This was illustrated by a diagram. Lastly, the lecturer explained the principles according to which the steadiness of a ship at sea is affected by storm-waves, and the difference between the properties of steadiness and stiffness. The mathematical theory of the stability of ships had been known and applied with useful results for nearly a century; but in the course of the last ten years it had received some important additions, due especially to the researches of Mr. Froude on the manner in which the motions of the waves affect the rolling of the vessel. A stiff ship is one that tends strongly to keep and to recover her position of uprightness to the surface of the water. A steady ship is one that tends to keep a position of absolute uprightness. In smooth water these properties are the same; and a stiff ship is also a steady ship. Amongst waves, on the other hand, the properties of stiffness and steadiness are often opposed to each other. A stiff ship tends as she rolls, to follow the motions of the waves as they roll. She is a dry ship; but she may be what is called uneasy, through excessive rolling along with the waves. The property of stiffness is possessed in the highest degree by a raft, and by a ship which, like a raft, is broad and shallow, and whose natural period of rolling in smooth water is very short compared with the periodic time of the waves. In order that a ship may be steady among waves, her natural period of rolling should be considerably longer than that of the waves; and in order that this property may be obtained without making the vessel crank, the masses on board of her should be spread out sideways as far as practicable from her centre of gravity; this is called "winging out the weights." A vessel whose natural period of rolling in smooth water is only a little shorter or a little longer than that of the waves, has neither the advantages of stiffness nor those of steadiness, for she rolls to an angle greater than that of the slope of the waves; and her condition is specially unsafe if her natural period of rolling is a little greater than that of the waves, for then she tends to heel over towards the nearest wave-crest, to the danger of its breaking over her deck. This is called "rolling against the waves." The most dangerous condition is that of a vessel whose period of rolling in smooth water is equal to that of the waves that she encounters, for then every successive wave makes her roll through a greater angle; and under these circumstances no ship can be safe, how great soever her statical stability. All these principles have been known for some years through Mr. Froude's researches. The lecturer exhibited a machine he had contrived for illustrating them, in which the dynamical conditions of vessels of different degrees of stiffness and steadiness were approximately imitated by means of a peculiarly-constructed pendulum hanging from a pin, whose motions imitate those of a particle of water disturbed by waves.

SECTIONAL PROCEEDINGS

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE

On the Mode of Action of Lightning on Telegraphs, and on a New Method of Constructing Telegraph Coils.—Mr. S. Alfred Varley. He remarked that when lightning storms occur in the neighbourhood of telegraph wires, although the wires may not be actually struck, powerful currents are induced in them which may be sufficiently strong to fuse the coils, but which more frequently simply demagnetise, and as often reverse the magnetism of the magnetic needles situated in the coils of needle telegraph instruments. Thus, not only is a considerable amount of damage done annually to telegraph instruments, but telegraphic communication is very liable to serious interruption. Mr. Varley mentioned a number of observations going to prove that an interval of dust separating two metallic conductors opposes practically a decreasing resistance to an increasing electrical tension, and that incandescent particles of carbon oppose about $\frac{1}{60}$th part of the resistance opposed by a needle telegraph coil. Reasoning upon these data, he has constructed an instrument, the main feature of which is what he terms a "lightning bridge." Two thick metal conductors, terminating in points, are inserted usually in a piece of wood. These points approach one another within about $\frac{1}{18}$th of an inch in a chamber cut in the middle of the wood. This bridge is placed in the electric circuit in the most direct course which the lightning can take, and the space separating the two points is filled loosely with powder, which is placed in the chamber, and surrounds and covers the extremities of the pointed conductors. The powder employed consists of carbon (a conductor) and a non-conducting substance in a minute state of division. When this instrument is used, therefore, lightning which strikes a circuit finds in its direct path not a space of air but a bridge of powder, consisting of particles of conducting matter in close proximity to one another. These the lightning connects under the influence of the discharge, and the particles are thrown into a highly incandescent state. The secondary current, developed by the demagnetisation, finds an easier passage across this heated matter than through the coils. These lightning bridges have been in use since January 1866, and at the present moment there are upwards of 1,000 doing duty in this country alone. Yet not a single case has occurred of a coil being fused when protected by them. The reason why a powder consisting entirely or chiefly of conducting matter cannot be safely employed is, that although it can oppose a practically infinite resistance to the passage of electricity of the tension of ordinary working currents, when a high tension discharge occurs, the particles under the influence of the discharge generally arrange themselves so closely as to make a conducting connection between the two points of the lightning bridge. In the course of his exposition, Mr. Varley endeavoured to prove that when telegraphic circuits protected by ordinary protectors are struck by lightning, it is to the secondary current and not to the main discharge that the fusion must be attributed. He also pointed out the defects of the protector, which consists of two silk wires wound side by side upon a bobbin.

Mr. Varley also read a second paper containing *A Description of the Electric Time Signal, at Port Elizabeth, Cape of Good Hope.* After an elaborate account of the Liverpool time ball, he proceeded to say that in the year 1859, Sir Thomas Maclear, the Astronomer Royal of the Cape of Good Hope, inspected the electrical time signals in this country, with a view to erecting time balls in connection with the Royal Observatory at Cape Town. Sir T. Maclear remarked the greater rapidity of action of the Liverpool trigger, and this led to Mr. Varley's afterwards designing and constructing at different times two triggers for use in the Cape. Both these triggers discharged more rapidly than the Liverpool trigger. In September 1864, he was requested to construct a trigger for discharging a time ball to be erected at Port Elizabeth. He considered the intervention of any relay or secondary apparatus to be objectionable. He therefore determined if possible to construct the trigger sensitive enough to be discharged by the batteries in the Cape Town Observatory, and in its construction he adopted a modification of a principle first introduced by Professor Hughes in his printing telegraph (described at the Newcastle meeting).

The trigger was constructed with a soft iron armature, rendered magnetic by induction from a compound bar magnet, and which strongly attracted the soft iron cores of an electro-magnet, but which was prevented from actually touching the poles of the electro-magnet.

A spiral spring attached to this armature was so adjusted that it nearly overcame the magnetic attraction induced by the bar magnets.

The time current polarised the electro-magnet in the opposite direction to that induced by the bar magnets, and as the attraction between the armature and the soft iron cores was already almost overcome by the spiral spring, a very small amount of polarisation in the opposite direction was necessary to release the armature, which was rapidly pulled away by the spiral spring, and the trigger discharged.

There were some other alterations made in the general mechanical construction of this trigger, but they may be regarded as matters of detail.

The rapidity of discharge was very great, $\frac{1}{20}$th part of a second only elapsed between the arrival of the time current and the falling of the ball.

From a report in the Port Elizabeth paper of August 29, 1865, giving an account of the inauguration of this time signal, and forwarded to Mr. Varley by Sir Thomas Maclear, it appears that the time elapsing between the time current leaving the Observatory at Cape Town and the receipt at Cape Town of the signal announcing the falling of the ball, is only $\frac{1}{16}$th of a second.

The time which elapsed between the Greenwich current reaching London and the falling of the ball at Liverpool was $\frac{11}{20}$th of a second. In other words, the Algoa ball is discharged from a distance of 500 miles in less than $\frac{1}{7}$th of the time of that of the Liverpool ball.

What is being daily done in the Cape can, however, be best summed up by a short quotation from a letter received from Sir Thomas Maclear, giving an account of the successful inauguration of this time signal. After detailing the general arrangements, Sir Thomas Maclear goes on to state: "A few tentative signals having proved satisfactory, the 'preface' was issued from the Observatory at ten minutes before one o'clock, and at the instant of one o'clock, the Observatory time-ball clock closed the circuit discharging the Observatory ball, the Simon's Town ball, twenty-four miles distant; the Cape Town time gun, three miles distant; and the Port Elizabeth ball, distant 500 miles."

On the present State of the Question relative to Lunar Activity or Quiescence.—W. R. Birt, F.R.A.S. From the time of Schröter, the question of change on the moon's surface has been more or less agitated. The *Selenotopographische Fragmente* contains numerous instances of what he considered to be changes of a temporary character, and a few of a more permanent nature, as the formation of new craters. It is, however, notorious that he failed to establish the fact of a decided change in any one instance; nor is this to be wondered at when we consider the paucity of the materials he had at his command. Notwithstanding the comparative neglect into which the observations recorded in the "Fragments" have fallen, and the judgments passed upon them by some of the best known selenographers, there can be no question that they embody the results of zealous and persevering attention to the moon's surface, and ought not to be passed over in the examination of any given spot, the history of which we are desirous of becoming acquainted with *during the earliest period of descriptive observational selenography.*

The labours of Schröter's successors, Lohrmann, and Beer and Mädler, have added greatly to the number of objects, either as delineated on their maps or referred to in their letter-press. Lohrmann appears to have carefully studied Schröter's results, as we find him quoting the measures obtained by Schröter in several instances. On examining the results of the two greatest selenographical works of the present century, and comparing the one with the other, we find precisely the same kind of phenomena presenting themselves which in a great measure perplexed Schröter; but as Lohrmann and Mädler worked independently of each other, and Mädler evidently had a very low idea of the value of the preceding labours of Schröter, these phenomena